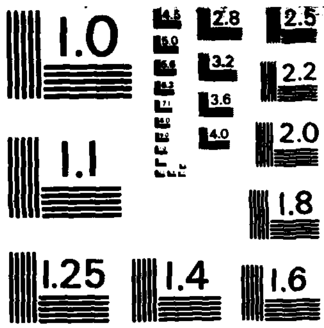
AD-A139 798 PANASONIC HR-1800 HAND-HELD COMPUTER SOLUTIONS TO COMPOSITE MATERIALS FOR..(U) UNIVERSAL ENERGY SYSTEMS INC DAYTON OH T N MASSARD ET AL. SEP 83 1/1

UNCLASSIFIED AFWAL-TR-83-4093 F33615-82-C-5001 F/G 9/2 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

AFWAL-TR-83-4093

PANASONIC HR-1800 HAND-HELD COMPUTER SOLUTIONS TO COMPOSITE MATERIALS FORMULAS

Thierry N. Massard
Mechanics and Surface Interactions Branch
Nonmetallic Materials Division

and

Won J. Park
Universal Energy Systems, Inc.
Dayton, Ohio 45432

September 1983

Final Report for Period September 1982 - June 1983

MATERIALS LABORATORY
AIR FORCE WRIGHT AERONAUTICAL LABORATORIES
AIR FORCE SYSTEMS COMMAND
WRIGHT-PATTERSON AFB, OHIO 45433

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This report has been reviewed by the Office of Public Affairs (ASD/PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

S.W. Tsai

S.W. TSAI, Project Engineer & Chief
Mechanics and Surface Interactions Branch
Nonmetallic Materials Division

FOR THE COMMANDER

F.D. Cherry

F. D. CHERRY, Chief
Nonmetallic Materials Division

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER
AFWAL-TR-83-4093

2. GOVT ACCESSION NO.
AD-A139798

3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle)
PANASONIC HR-1800 HAND-HELD COMPUTER SOLUTIONS TO COMPOSITE MATERIALS FORMULAS

5. TYPE OF REPORT & PERIOD COVERED
September 1982 - June 1983

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s)

Thierry N. Massard
Won J. Park

8. CONTRACT OR GRANT NUMBER(s)
F33615-82-C-5001
SB5448-82-C-0086

9. PERFORMING ORGANIZATION NAME AND ADDRESS

Materials Laboratory
Wright-Patterson AFB, OH 45433
Universal Energy Systems, Inc.
Dayton, OH 45432

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
2307P201

11. CONTROLLING OFFICE NAME AND ADDRESS
Materials Laboratory (AFWAL/MLBM)
Air Force Wright Aeronautical Laboratories
Wright-Patterson AFB, OH 45433

12. REPORT DATE
September 1983

13. NUMBER OF PAGES
27

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)

15. SECURITY CLASS. (of this report)
Unclassified

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)
Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES
This program uses the language of BASIC.
The computer program(s) contained in this technical report is (are) theoretical and in no way reflect(s) any Air Force owned software programs.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)
BASIC Programming
Composite Materials
Properties of Unidirectional and Laminated Composite
In-Plane and Flexural Stiffness and Strength
Buckling of Orthotropic Simply Support Plate

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This volume contains the description and instructions of the use of Panasonic HR-1800 Hand-Held Computer for the key calculations of the stiffness and strength of symmetric laminated composites. Instant calculations can be made for practical use. The formulas and equation numbers used in the performed programming have been derived in a book entitled, Introduction to Composite Materials, co-authored by S. W. Tsai and H. T. Hahn, published by Technomic Publishing Company, Westport, Connecticut, July 1980.

FOREWORD

This report was prepared in the Mechanics and Surface Interactions Branch (AFWAL/MLBM), Nonmetallic Materials Division, Materials Laboratory, Air Force Wright Aeronautical Laboratories, Wright-Patterson AFB, Ohio. This work was performed under Contract F33615-82-C-5001; SB5448-82-C-0086.

This time period covered by this report was from September 1982 to June 1983. Dr. Thierry N. Massard is a Visiting Scientist at the Materials Laboratory, Air Force Wright Aeronautical Laboratories, Wright-Patterson AFB, Ohio, and a Chief Engineer at the Commissari at L' Energie Atomique, Montrouge, France.

Dr. Won J. Park is a Senior Scientist from Universal Energy Systems, Inc. and Professor of Mathematics and Statistics at Wright State University.

The equations and table numbers which appear in the flow charts are the same as in Introduction to Composite Materials, co-authored by S. W. Tsai and H. T. Hahn, published by Technomic Publishing Company, Westport, Connecticut, in July 1980.

TABLE OF CONTENTS

SECTION I

USER GENERAL INSTRUCTION

(1) The program language for HR-1800 Hand-Held Computer is BASIC from the Microsoft BASIC ROM attached to the computer.

(2) The capacity of the computer is 8k RAM (model HR-1800). The printer is optional.

(3) The program is called SYM-LAM (for symmetric laminates). The program considers only symmetric laminates of composite materials and is restricted to orthotropic materials for the buckling calculations.

SECTION II

CONTENTS OF THE PROGRAM

The program performs scientific operations and computations of composite materials.

(1) In-plane stiffness of symmetric laminates and matrix conversion.

(2) Engineering constants.

(3) Normalized in-plane stiffness and matrix inversion.

(4) In-plane strength of symmetric laminates.

(5) Flexural stiffness of symmetric sandwich plate and matrix inversion.

(6) Engineering flexural constants.

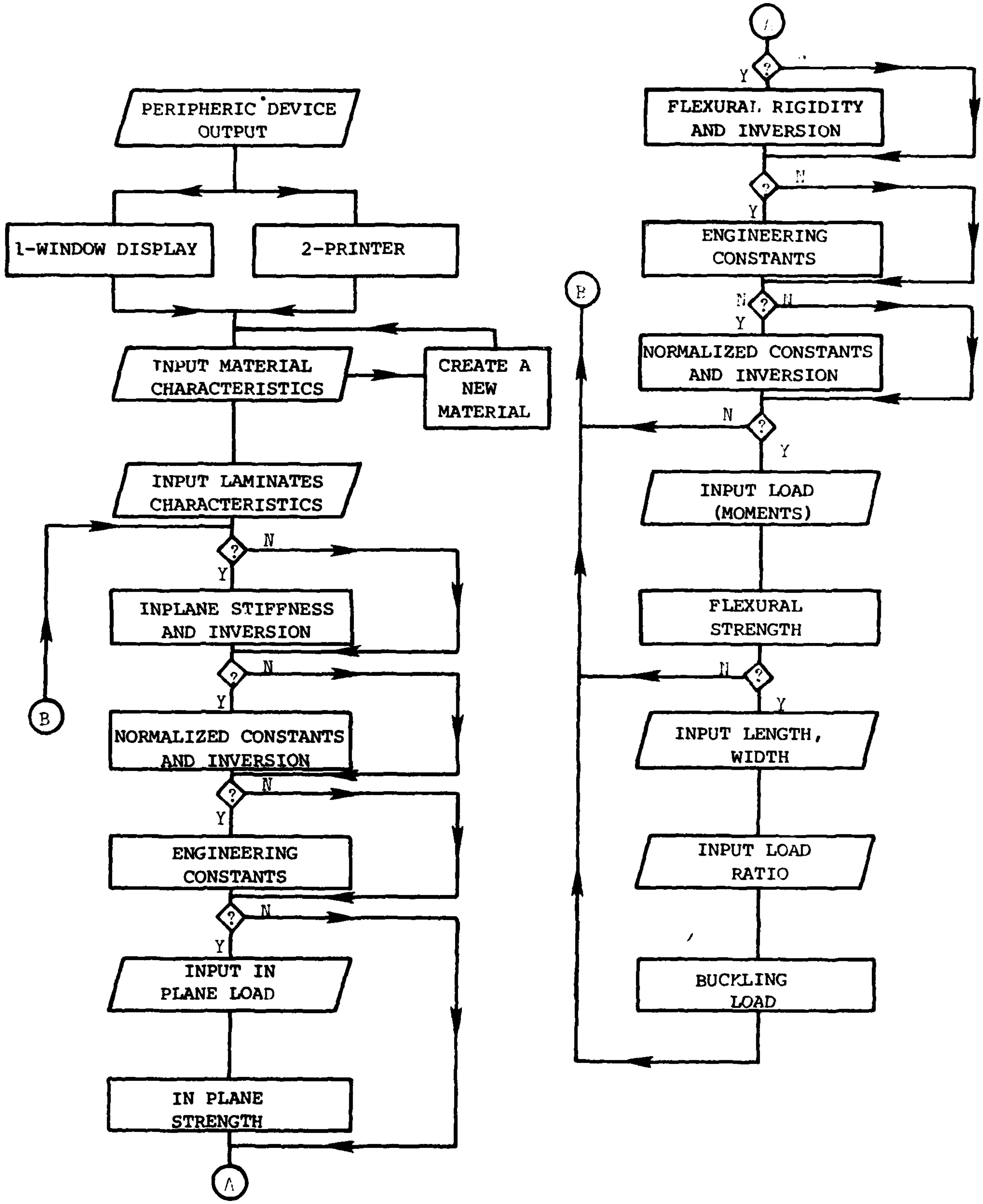
(7) Normalized flexural rigidity of sandwich plate and matrix inversion.

(8) Flexural strength of sandwich plate.

(9) Buckling load and modes of a simply supported rectangular plate subjected to two axial loads. (ORTHOTROPIC MATERIALS ONLY) Reference: Mechanics of Composite Materials, R. M. Jones, MacGraw Hill .

SECTION III
PROCEDURE

1. FLOW DIAGRAM



2. KEY OPERATION PROCEDURE

Display	Operation	Print Out & Remarks
	R U N	can be a function key f_1 or f_2 or f_3
	ENTER	
1 - LCD or 2 - printer	2 * ENTER	1 will give results on the display window 2 will give results on the printer
Material (m for menu)?	M *	Available data (4 materials) 1-T300/5208 2-ALUMINIUM 3-KEVLAR/EPOXY 4-GLASS/EPOXY Instructions to create new materials data TO INPUT A NEW MATERIAL (number N)· TYPE THE FOLLOWING LINE: 10*N DATA Ex,Ey,vx,Es,t,X X',Y, Y', S ·INCREMENT N IN LINE 1820
Material (m for menu)?	1 *	the laminate can use only one material
	ENTER	T300/5208
No. of angles		definition of the laminate
	2 *	
	ENTER	the laminate is $[0_4/90_4]_s$
	90 *	
angle = ? number of plies = ?	ENTER 4 * ENTER	layer nearer the midplane **************** ANGLE 1 = 0 Number of plies = 4
angle = ? number of plies = ?	0 * ENTER 4 * ENTER	layer on the outside **************** ANGLE 2 = 90 Number of plies = 4

*user' choice

<table>
<tr><th>Display</th><th>Operation</th><th>Print Out & Remarks</th></tr>
<tr><td>Number of Core Plies?
(flexural)</td><td>[0] *
[ENTER]</td><td>The core has no mechanical property. The ply thickness is the same than the laminate of the faces.
n. of core
plies = 0</td></tr>
<tr><td>In plane calculation
-Y/N?</td><td>[Y] *
[ENTER]</td><td>IN PLANE
CONSTANTS

STIFFNESS
in MN/m
A11 192.157298
A22 192.157298
A12 5.79384891
A66 14.34
A16 0
A26 0

COMPLIANCE
in m/KN
a11 5.20880528
a22 5.20880528
a12 -.157053784
a66 69.7350069
a16 0
a26 0</td></tr>
<tr><td>Engineering CST
Y/N?</td><td>[Y] *
[ENTER]</td><td>ENGINEERING
CONST.

E1-o 95.991 GPa
E2-o 95.991 GPa
E6-o 7.17 GPa
v21-o .03
v12-o .03
v61-o 0
v16-o 0
v62-o 0
v26-o 0</td></tr>
</table>

Display	Operation	Print Out & Remarks
Normalized Constants Y/N?	Y*	
	ENTER	STIFFNESS in GPa A*11 96.0786488 A*22 96.0786488 A*12 2.89692445 A*66 7.17000001 A*16 0 A*26 0 COMPLIANCE in TPa-1 a*11 10.4176106 a*22 10.4176106 a*12 -.314107569 a*66 139.470014 a*16 0 a*26 0
In plane strength Y/N?	Y*	
	ENTER	
N1 = (MN/m)?	1*	
	ENTER	
N2 = (MN/m)?	0*	
	ENTER	
N6 = (MN/m)?	0*	
	ENTER	IN PLANE STRENGTH N1 = 1 MN/m N2 = 0 MN/m N6 = 0 MN/m =====1 ===== angle 1 = 90 R+ = .746808548 n+ = 22 Sgm+ = 373.404274 MPa R- = 4.53828452 n- = 2 Sgm- = -2269.14226 MPa =====2 ===== angle 2 = 0 R+ = 1.36378965 n+ = 12 Sgm+ = 681.894823 MPa R- = 2.21547827 n- = 6 Sgm- = -1107.73914 MPa

Display	Operation	Print Out & Remarks
Flexural calculations Y/N?	[Y] * [ENTER]	FLEXURAL CONSTANTS STIFFNESS in Nm D11 106.918678 D22 21.1861875 D12 1.93128297 D66 4.78000001 D16 0 D26 0 ---------------- COMPLIANCE in (Nm)-1 d11 9.36832861 d22 47.2784122 d12 -.853994778 d66 209.205021 d16 0 d26 0
Engineering CST Y/N?	[Y] * [ENTER]	ENGINEERING CONST. E1-+ 160.113 GPa E2-f 31.726 GPa E6-f 7.17 GPa v21-f .091 v12-f .018 v61-f 0 v16-f 0 v62-f 0 v26-f 0
Normalized CST Y/N?	[Y] * [ENTER]	STIFFNESS in GPa D*11 160.378016 D*22 31.7792812 D*12 2.89692445 D*66 7.17000001 D*16 0 D*26 0

Display	Operation	Print Out & Remarks
		COMPLIANCE in TPa-1 d*11 6.24555241 d*22 31.5189415 d*12-.569329852 d*66 139.470014 d*16 0 d*26 0
Flexural Strength Y/N?	[Y] * [ENTER]	
M1 = ? (MN) M2 = ? (MN) M6 = ? (MN)		FLEXURAL STRENGTH M1 = 1 MN M2 = 0 MN M6 = 0 MN === 1 ==== angle 1 = 90 R+ = 8.85874406E-04 Sgm+ = 253.81161 MPa R- = 4.31521825E-03 Sgm- = -7222.82739 MPa ==== 2 ==== angle 2 = 0 R+ = 7.9212116E-04 Sgm+ = 1188.18174 MPa R- = 1.13734025E-03 Sgm- = -1706.01038 MPa

Display	Operation	Print Out & Remarks
Buckling Y/N?	Y ENTER	
Length & width in m?	1 ENTER .1 ENTER	BUCKLING dim. of the plate (l, w, t) is (1, .1, 2E-03) load ratio (N2/N1) is 0 critical load .133719444 MN/m 0 MN/m mode 5,1
Load N1, N2 in MN/m?	1 ENTER 0 ENTER	
		Load ratio is N2/N1. The dimension of the plate is: length, width, thickness. The buckling mode is given by mode i, j where i is the mode in length and j is the mode in width.
In plane calculations. Y/N?		The program restart to the first question. To study an other laminate strike key C1 (break) and F3 (RUN)

3. MEMORY CONTENT

MEMORY	DESCRIPTION	VERSION 1	VERSION 2	VERSION 3	MEMORY	DESCRIPTION	VERSION 1	VERSION 2	VERSION 3	MEMORY	DESCRIPTION	VERSION 1	VERSION 2	VERSION 3
A	E_x				KB	calculation				A(6)	$\nu_{61}^{o}, \nu_{61}^{f}$			
B	E_y				KC					A(7)	$\nu_{16}^{o}, \nu_{16}^{f}$			
C	ν_x				KD					A(8)	$\nu_{62}^{o}, \nu_{62}^{f}$			
D	E_s				KE					A(9)	$\nu_{26}^{o}, \nu_{26}^{f}$			
E	h_o				TT	control variable				B(1)	N^+			
F	$m=(1-\nu_x\nu_y)^{-1}$				XX	scale (10^a) factor				B(2)	N^-			
I	control variable				P	X				B(3)	σ^+			
J	"				Q	X'				B(4)	σ^-			
N	"				R	Y				T(1)	F_{xx}			
Z	"				S	Y'				T(2)	F_x			
CO	cosine θ				T	S				T(3)	F_{yy}			
SI	sine θ				U	calculation variable				T(4)	F_y			
TR	variable for trigonometric				A(1)	E_1^o, E_1^f				T(5)	F_{ss}			
TY	calculations				A(2)	E_2^o, $E_2 f$				T(6)	F_{xy}			
TX					A(3)	E_6^o , E_6^f				T(7)	G_{xy}			
TF					A(4)	$\nu_{12}^{o}, \nu_{12}^{f}$				T(8)	G_{yy}			
KA	constants for trigonometric				A(5)	$\nu_{21}^{o}, \nu_{21}^{f}$				T(9)	G_{xy}			

MEMORY	DESCRIPTION	VERSION			MEMORY	DESCRIPTION	VERSION			MEMORY	DESCRIPTION	VERSION		
		1	2	3			1	2	3			1	2	3
W1	G_{ss}				B$(6)	"26"				V(1)	invariants of the G_{ij} tensor			
W2	G_x				B$(9)	"E1-"				V(2)	"			
W3	G_y				B$(10)	"E2-"				V(3)	"			
E1	ε_1				B$(11)	"E6-"				V(4)	"			
E2	ε_2				B$(12)	"ν21-"				V(5)	"			
E6	ε_6				B$(13)	"ν12-"								
V(I)	A_{ij} D_{ij}				B$(14)	"ν61-"								
Y(I)	angle of each ply				B$(15)	"ν16-"								
Z(I)	number of plies for each angle				B$(16)	"ν62-"								
X(I)	calculations variable				B$(17)	"ν26-"								
A$(1)	="stiffness"				Z$	output variable								
A$(2)	="compliance"				G$	"Y", "N"								
B$(1)	="11"				U(1)	invariants of the Q_{ij} tensor								
B$(2)	"22"				U(2)	"								
B$(3)	"12"				U(3)	"								
B$(4)	"66"				U(4)	"								
B$(5)	"16"				U(5)	"								

4. SAMPLE PROBLEMS

C-1 T300/5208 $[0_1/90_1/\pm45_1]_s$

4 core plies

$N_1 = 1$ MN/m $N_2 = N_6 = 0$

$M_1 = 1$N $M_2 = M_6 = 0$

C-2 T300/5208 $[0_4/90_4]_s$

no core

$N_1 = 1$ MN/m $N_2 = N_6 = 0$

$M_1 = 0$, $M_2 = 1$N, $M_6 = 0$

$M_1 = 1$N, $M_2 = 0$ $M_6 = 0$, $M_1 = 1$MN, $M_2 = 0$, $M_6 = 0$

C-3 Kevlar/Epoxy Sandwich $[\pm30_4]_s$

10 core ply

$N_1 = 1$ MN/m $N_2 = N_6 = 0$

$M_2 = 1$ MN $M_2 = M_6 = 0$

SAMPLE PROBLEM C-1

```
1 -T300/5208
2 -ALUMINIUM
3 -KEVLAR/EP
4 -GLASS/EPX

T300/5208
************
ANGLE 1 = 0
number of Plies
= 1
************
ANGLE 2 = 90
number of Plies
= 1
************
ANGLE 3 = 45
number of Plies
= 1
************
ANGLE 4 =-45
number of Plies
= 1
n. of core
Plies= 4
------------
IN PLANE
CONSTANTS

STIFFNESS
in  MN/m
A11 76.3682178
A22 76.3682176
A12 22.6073556
A66 26.8804311
A16 0
A26 0
------------

COMPLIANCE
 in  m/kN
a11 14.3521976
a22 14.3521976
a12-4.24869459
a66 37.2017843
a16 0
a26 0
------------
ENGINEERING
CONST.

E1-o 69.675 GPa
E2-o 69.675 GPa
E6-o 26.88 GPa
v21-o .296
v12-o .296
v61-o 0
v16-o 0
v62-o 0
v26-o 0
------------

STIFFNESS
 in  GPa
A*11 76.3682178
A*22 76.3682176
A*12 22.6073556
A*66 26.8804311
A*16 0
A*26 0
------------

COMPLIANCE
 in  TPa-1
a*11 14.3521976
a*22 14.3521976
a*12-4.2486946
a*66 37.2017843
a*16 0
a*26 0
------------

IN PLANE
STRENGTH

N1= 1 MN/m
N2= 0 MN/m
N6= 0 MN/m
====== 1 ======
angle 1=-45
R+= .347657121
n+= 24
Sgm+=
347.657121 MPa
R-= .677583674
n- =  10
Sgm- =
-677.583674 MPa
====== 2 ======
angle 2= 45
R+= .347657122
n+= 24
Sgm+=
347.657122 MPa
R-= .677583674
n- =  10
Sgm- =
-677.583673 MPa
====== 3 ======
angle 3= 90
R+= .276743756
n+= 30
Sgm+=
276.743756 MPa
R-= 1.31149767
n- =  6
Sgm- =
-1311.49767 MPa

====== 4 ======
angle 4= 0
R+= .58297431
n+= 14
Sgm+= 582.97431
MPa
R-= .566515812
n- =  14
Sgm- =
-566.515812 MPa
------------
FLEXURAL
CONSTANTS

STIFFNESS
in  Nm
D11 52.9323284
D22 43.5553373
D12 9.49191825
D66 11.9845457
D16 1.67446269
D26 1.67446273
------------

COMPLIANCE
 in  (Nm)-1
d11 19.716124
d22 23.9837143
d12-4.21341993
d66 34.1293669
d16-2.16601447
d26-2.76227597
------------
ENGINEERING
CONST.

E1-f 76.079 GPa
E2-f 62.542 GPa
E6-f 17.829 GPa
v21-f .213
v12-f .175
v61-f-.11
v16-f-.026
v62-f-.116
v26-f-.033
------------

STIFFNESS
 in  GPa
D*11 79.3984926
D*22 65.3330059
D*12 14.2378774
D*66 17.9768185
D*16 2.51169403
D*26 2.5116941
------------
```

SAMPLE PROBLEM C-1 (Cont'd)

COMPLIANCE
in TPa-1
a*11 13.1440826
a*22 15.9891429
a*12-2.80894662
a*66 56.0862446
a*16-1.44400964
a*26-1.84151725

FLEXURAL
STRENGTH
M1= 1 MN
M2= 0 MN
M6= 0 MN
====== 1 ======
angle 1=-45
R+=
4.12495439E-04
Sgm+=
618.743159 MPa
R-=
8.42675678E-04
Sgm- =
-1264.01352 MPa
====== 2 ======
angle 2= 45
R+=
3.24260165E-04
Sgm+=
486.390249 MPa
R-=
7.4321028E-04
Sgm- =
-1114.81542 MPa
====== 3 ======
angle 3= 90
R+=
2.28829112E-04
Sgm+=
343.243669 MPa
R-=
1.16682481E-03
Sgm- =
-1750.23723 MPa
====== 4 ======
angle 4= 0
R+=
4.04691727E-04
Sgm+=
607.037591 MPa
R-=
4.57058315E-04
Sgm- =
-685.587474 MPa

BUCKLING
dim. of the
Plate(l,w,t) 1
.1 2E-03
load ratio
(N2/N1) is 0
critical load:
.252981111 MN/m
0 MN/m
mode 5 , 1

SAMPLE PROBLEM C-2

```
1 -T300/5208
2 -ALUMINIUM
3 -KEVLAR/EP
4 -GLASS/EPX

T300/5208
************
ANGLE 1 = 0
number of Plies
= 4
************
ANGLE 2 = 90
number of Plies
= 4
n. of core
Plies= 0
------------
IN PLANE
CONSTANTS

STIFFNESS
 in MN/m
A11 192.157298
A22 192.157298
A12 5.79384891
A66 14.34
A16 0
A26 0
------------

COMPLIANCE
 in m/MN
a11 5.20880528
a22 5.20880528
a12-.157053784
a66 69.7350069
a16 0
a26 0
------------
ENGINEERING
CONST.

E1-o 95.991 GPa
E2-o 95.991 GPa
E6-o 7.17 GPa
v21-o .03
v12-o .03
v61-o 0
v16-o 0
v62-o 0
v26-o 0
------------

STIFFNESS
 in GPa
A*11 96.0786488
A*22 96.0786488
A*12 2.89692445
A*66 7.17000001
A*16 0
A*26 0
------------

COMPLIANCE
 in TPa-1
a*11 10.4176106
a*22 10.4176106
a*12-.314107569
a*66 139.470014
a*16 0
a*26 0
------------

IN PLANE
STRENGTH

N1= 1 MN/m
N2= 0 MN/m
N6= 0 MN/m
====== 1 ======
angle 1= 90
R+= .746808548
n+= 12
Sgm+=
673.404274 MPa
R-= 4.53828452
n- = 2
Sgm- =
-2269.14226 MPa
====== 2 ======
angle 2= 0
R+= 1.36378965
n+= 12
Sgm+=
681.894823 MPa
R-= 2.21547827
n- = 6
Sgm- =
-1107.73914 MPa
------------
FLEXURAL
CONSTANTS

STIFFNESS
 in Nm
D11 106.918678
D22 21.1861875
D12 1.93128297
D66 4.78000001
D16 0
D26 0
------------

COMPLIANCE
 in (Nm)-1
d11 9.36832861
d22 47.2784122
d12-.853994778
d66 209.205021
d16 0
d26 0
------------

ENGINEERING
CONST.

E1-f 160.113
GPa
E2-f 31.726 GPa
E6-f 7.17 GPa
v21-f .091
v12-f .018
v61-f 0
v16-f 0
v62-f 0
v26-f 0
------------

STIFFNESS
 in GPa
D*11 160.378016
D*22 31.7792812
D*12 2.89692445
D*66 7.17000001
D*16 0
D*26 0
------------

COMPLIANCE
 in TPa-1
d*11 6.24555241
d*22 31.5189415
d*12-.569329852
d*66 139.470014
d*16 0
d*26 0
------------
FLEXURAL
STRENGTH
M1= 0 MN
M2= 1E-06 MN
M6= 0 MN
====== 1 ======
angle 1= 90
R+= 318.180797
Sgm+= 477271197
MPa
R-= 555.029356
Sgm- =
-832544036 MPa
====== 2 ======
angle 2= 0
R+= 82.878661
Sgm+= 124317992
MPa
R-= 532.682322
Sgm- =
-799024235 MPa
------------
FLEXURAL
STRENGTH
M1= 1 MN
M2= 0 MN
M6= 0 MN
```

SAMPLE PROBLEM C-2 (Cont'd)

```
====== 1 ======
angle 1= 90
R+=
8.35574406E-04
Sgm+=
1253.81161 MPa
R-=
4.81521825E-03
Sgm- =
-7222.92799 MPa
====== 2 ======
angle 2= 0
R+=
7.92121116E-04
Sgm+=
1188.18174 MPa
R-=
1.13734025E-03
Sgm- =
-1706.01038 MPa
------------
FLEXURAL
STRENGTH
M1= 1E-06 MN
M2= 0 MN
M6= 0 MN
====== 1 ======
angle 1= 90
R+= 835.974403
Sgm+=
12538116.1 MPa
R-= 4815.21825
Sgm- =
-72229273.9 MPa
====== 2 ======
angle 2= 0
R+= 792.12116
Sgm+=
11881817.4 MPa
R-= 1137.34025
Sgm- =
-17060103.8 MPa
------------
BUCKLING
dim. of the
Plate(l,w,t)  1
 .1  2E-03
    load ratio
(N2/N1) is 0
critical load:
.133719444 MN/m
0 MN/m
 mode 5 , 1
```

SAMPLE PROBLEM C-3

1 -T300/5208
2 -ALUMINIUM
3 -KEVLAR/EP
4 -GLASS/EPX
KEVLAR/EP
****
ANGLE 1 = 30
number of Piles
= 4
****
ANGLE 2 =-30
number of Piles
= 4
n. of core
Plies= 10

IN PLANE
CONSTANTS

STIFFNESS
in MN/m
A11 31.7789415
A22 30.6841775
A12 29.7275564
A66 30.5560044
A16 0
A26 0

COMPLIANCE
in m/kN
a11 30.385644
a22 30.4543013
a12-29.2985003
a66 32.726792
a16 0
a26 0

ENGINEERING
CONST.

E1-o 24.527 GPa
E2-o 5.527 GPa
E6-o 15.278 GPa
v21-o 1.437
v12-o .323
v61-o 0
v16-o 0
v62-o 0
v26-o 0

STIFFNESS
in GPa
A*11 45.3894708
A*22 10.3420887
A*12 14.8637782
A*66 15.2780022
A*16 0
A*26 0

COMPLIANCE
in TPa-1
a*11 40.7712879
a*22 180.908603
a*12-58.5970007
a*66 65.453584
a*16 0
a*26 0

IN PLANE
STRENGTH

N1= 1 MN/m
N2= 0 MN/m
N6= 0 MN/m
====== 1 ======
angle 1=-30
R+= .250398912
n+= 64
Sgm+=
125.199456 MPa
R-= .0900191266
n- = 176
Sgm- =
-45.0095633 MPa
====== 2 ======
angle 2= 30
R+= .250398912
n+= 64
Sgm+=
125.199456 MPa
R-= .0900191266
n- = 176
Sgm- =
-45.0095633 MPa

FLEXURAL
CONSTANTS

STIFFNESS
in Nm
D11 238.721254
D22 65.0689752
D12 93.5179382
D66 96.1240974
D16 40.0493119
D26 13.824326

COMPLIANCE
in (Nm)-1
d11 6.6690807
d22 28.7603163
d12-9.27804033
d66 11.0438826
d16-1.44427301
d26-.270617426

ENGINEERING
CONST.

E1-f 19.745 GPa
E2-f 4.578 GPa
E6-f 11.923 GPa
V21-f 1.391
V12-f .322
V61-f-.217
V16-f-.131
V62-f-.01
V26-f-.025

STIFFNESS
in GPa
D*11 28.0209058
D*22 5.56875392
D*12 12.3151194
D*66 12.6583173
D*16 5.27398345
D*26 1.82048737

COMPLIANCE
in TPa-1
d*11 50.6433316
d*22 218.398652
d*12-70.4551188
d*66 83.3644834
d*16-10.9674482
d*26-2.05500108

FLEXURAL
STRENGTH
M1= 1 MN
M2= 0 MN
M6= 0 MN
====== 1 ======
angle 1=-30
R+=
4.5630055E-04
Sgm+=
125.200163 MPa
R-=
1.49437433E-04
Sgm- =
-44.2777579 MPa
====== 2 ======
angle 2= 30
R+=
3.44895089E-04
Sgm+=
102.191137 MPa
R-=
1.37431411E-04
Sgm- =
-40.7204179 MPa

BUCKLING
dim. of the
Plate(l w t) 1
.1 4.5E-03
load ratio
(N2/N1) is 0
critical load:
2.08863557 MN/m
0 MN/m
mode 5 1

4. PROGRAM LISTING

The program, when running, utilizes the whole 8k RAM (1117 bytes free before running, only two bytes free when running).

The program has two subroutines to perform trigonometric functions (SINE & COSINE). This part could be skipped by using the scientific ROM which could be attached on the hand-held computer. This ROM was not available at the time when we made the program.

The program can be saved on a programmable external memory, to transfer the software on other computers. No cassette or disc interface is built in the hand-held computers.

PROGRAM LISTING

```
5 ATTACH 68 TO
#2
10 INPUT "1-LCD
or
2-Printer";Z
30 DIM
X(10),Y(9),Z(9)
,V(12),A$(2),A(
9),B(4),B$(17),
NM(3)
34 DATA
"11","22","12",
"66","16","26"
,"","E1-","E2
-","E6-","v21-"
,"v12-"
36 DATA
"v61-","v16-","
v62-","v26-"
100 DATA
"T300/5208",181
E3,10.3E3,.28,7
.17E3,.125E-3,1
500,1500,40,246
,68
200 DATA
"ALUMINIUM",69E
3,69E3,.3,26.5E
3,1,400,400,400
,400,230
300 DATA
"KEVLAR/EP",76E
3,5.5E3,.34,2.3
E3,.125E-3,1400
,235,12,53,34
400 DATA
"GLASS/EPX",38.
6E3,8.27E3,.26,
4.14E3,.125E-3,
1026,610,31,118
,72
1300 INPUT
"MATERIAL m for
menu";G$
1310 RESTORE
:FOR I=1 TO
17:READ
B$(I):NEXT I
1820 N= VAL
(G$):IF
G$="m"THEN N=4
1825 FOR I=1 TO
N:READ
A$(0),A,B,C,D,E
,P,Q,R,S,T
1830 IF
G$="m"THEN
PRINT
#Z;I;"-";A$(0)
1835 NEXT I:IF
G$<>"m"THEN
GOTO 1850
1848 GOTO 1300
1850 PRINT
#Z;A$(0)
2000
A$(1)="STIFFNES
S":A$(2)="COMPL
IANCE"
2100 INPUT "No
of angles";G
2300
F=1/(1-C*C*B/A)
:X1=F*A:X2=F*B:
X3=F*C*B:X4=D
2310
U1=(3*X1+3*X2+2
*X3+4*X4)/8
2320
U2=(X1-X2)/2
2330
U3=(X1+X2-2*X3-
4*X4)/8
2340
U4=(X1+X2+6*X3-
4*X4)/8
2350
U5=(X1+X2-2*X3+
4*X4)/8
2355
T1=1/P/Q:T2=1/P
-1/Q:T3=1/R/S:T
4=1/R-1/S:T5=1/
T/T:O=-1/2
2360 T6=O*SQR
(T1*T3)
2380
T7=T1*X1^2+2*T6
*X1*X3+T3*X3^2
2390
T8=T1*X3^2+2*T6
*X3*X2+T3*X2^2
2400
T9=T1*X1*X3+T6*
(X1*X2+X3^2)+T3
*X3*X2
2405
W1=T5*X4^2:W2=T
2*X1+T4*X3:W3=T
2*X3+T4*X2
2410
V1=(3*T7+3*T8+2
*T9+4*W1)/8:V2=
(T7-T8)/2
2430
V3=(T7+T8-2*T9-
4*W1)/8:V4=(T7+
T8+6*T9-4*W1)/8
2450
V5=(T7+T8-2*T9+
4*W1)/8
2930 FOR I=1 TO
G
2940 INPUT
"angle=
";Y(G-I+1)
2950
H$="ANGLE"+STR$
(I)+" ="
2960 IF Z=2
THEN PRINT
#Z;"***********
*"
2970 PRINT
#Z;H$;Y(G-I+1)
2980 INPUT "No
of Plies
=";Z(G-I+1)
2990 PRINT
#Z;"number of
Plies
=";Z(G-I+1)
3000 NEXT I
3100 INPUT "No
of core
Plies=(<-lezur.)
";Z(0)
3200 PRINT
#Z;"n. of core
Plies=";Z(0)
3400 INPUT "In
Plane
calculation
-y/n";G$
3500 X$="IN
PLANE
CONSTANTS"
3600 GOSUB 6800
3700 FOR I=1 TO
G:GOSUB 7000
3710
U=2*Z(I)*E:X(10
)=X(10)+U
3720 FOR J=1 TO
6:V(J)=V(J)+U*X
(J):NEXT J:NEXT
I
3750
I$="A":N=1:TT=0
:XX=1:U$="MN/m"
:IF G$="y"THEN
GOSUB 3800
3770 GOTO 5400
3800 GOSUB
51000:PRINT
#Z;X$,A$(N);"in
";U$
3900 FOR I=1 TO
6:W=1:IF ABS
(V(I+TT)*XX)<1E
-4 THEN LET W=0
4000 PRINT
#Z;I$+B$(I);V(I
+TT)*XX*W:NEXT
I:RETURN
4970
U$="GPa":GOSUB
51000:PRINT
#Z;"ENGINEERING
CONST.";PRINT
#Z
```

PROGRAM LISTING (Cont'd)

```
5000 FOR I=1 TO
9:XX=1E-3:IF
I>3 THEN LET
XX=1:U$=""
5050 IF ABS
(A(I))<1E-6
THEN LET A(I)=0
5100 PRINT
#2:B$(I+8)+Z$;1
E-3*INT
(1E3*A(I)*XX);U
$
5150 NEXT
I:RETURN
5400 GOSUB
3000:X$="":Z$="
a":N=2:TT=6:XX=
1E3:U$="m/kN":I
F G$="y"THEN
GOSUB 3800
5800 GOSUB
12000
5900
Z$="o":INPUT
"length.
const.-y/n
";G$:IF
G$="y"THEN
GOSUB 4970
6000 INPUT
"norm.
const.y/n ";G$
6050
Z$="A*":N=1:TT=
0:XX=1E-3:U$="G
Pa"
6060 IF
G$="y"THEN
GOSUB
12300:GOSUB
3800
6150
Z$="a*":N=2:TT=
6:XX=1E6:U$="TP
a-1":IF
G$="y"THEN
GOSUB
3800:GOSUB
12400
6200 GOTO 13000
6800 FOR I=1 TO
6:V(I)=0:NEXT
I:RETURN
7000 GOSUB
50000:TX=2*Y(I)
:GOSUB
50100:S2=TR:GOS
UB 50120:C2=TR
7010
TX=4*Y(I):GOSUB
50100:S4=TR:GOS
UB 50120:C4=TR
```

```
7100
X(1)=U1+C2*U2+C
4*U3
7200
X(2)=U1-C2*U2+C
4*U3
7300
X(3)=U4-C4*U3
7400
X(4)=U5-C4*U3
7500
X(5)=S2*U2/2+S4
*U3
7600
X(6)=S2*U2/2-S4
*U3:RETURN
3000
DT=V(1)*V(2)*V(
4)+2*V(3)*V(6)*
V(5)-V(2)*V(5)^
2-V(1)*V(6)^2-V
(4)*V(3)^2
3200
V(7)=(V(2)*V(4)
-V(6)^2)/DT
3250
V(8)=(V(1)*V(4)
-V(5)^2)/DT
3300
V(9)=(V(5)*V(6)
-V(3)*V(4))/DT
3400
V(10)=(V(1)*V(2
)-V(3)^2)/DT
3500
V(11)=(V(3)*V(6
)-V(2)*V(5))/DT
3600
V(12)=(V(3)*V(5
)-V(1)*V(6))/DT
:RETURN
12000
A(1)=1/X(10)/V(
7):A(2)=1/X(10)
/V(8):A(3)=1/X(
10)/V(10)
12100
A(4)=-V(9)/V(7)
:A(5)=-V(9)/V(8
):A(6)=V(11)/V(
7)
12200
A(7)=V(11)/V(10
):A(8)=V(12)/V(
8):A(9)=V(12)/V
(10):RETURN
12300 FOR J=1
TO
6:V(J)=V(J)/X(1
0):V(J+6)=V(J+6
)*X(10):NEXT
J:RETURN
```

```
12400 FOR J=1
TO
6:V(J)=V(J)*X(1
0):V(J+6)=V(J+6
)/X(10):NEXT
J:RETURN
13000 INPUT
"strength
-y/n";G$:IF
G$<>"y"GOTO
27000
13200 GOSUB
51000:PRINT
#2:PRINT #2:"IN
PLANE
STRENGTH":PRINT
#2
13400
Z$="N":U$="MN/m
":GOSUB
13900:GOSUB
14200:GOTO
14500
13900 FOR I=11
TO
13:G$=Z$+MID$(B
$(I-2),3,1)+"=
:PRINT
G$+" "+U$+" "
13950 INPUT
NM(I-10):PRINT
#2:G$;NM(I-10);
U$:NEXT
I:RETURN
14200
E1=V(7)*NM(1)+V
(9)*NM(2)+V(11)
*NM(3)
14300
E2=V(9)*NM(1)+V
(8)*NM(2)+V(12)
*NM(3)
14400
E6=V(11)*NM(1)+
V(12)*NM(2)+V(1
0)*NM(3):RETURN

14500 FOR I=1
TO
6:A$="angle"+ST
R$(I)+"="
15000 GOSUB
15500:NEXT
I:GOTO 27000
15500 GOSUB
50000:TX=2*Y(I)
:GOSUB
50100:S2=TR:GOS
UB 50120:C2=TR
15550
TX=4*Y(I):GOSUB
50100:S4=TR:GOS
UB 50120:C4=TR
```

PROGRAM LISTING (Cont'd)

```
15600
G1=V1+C2*V2+C4*
V3
15650
G2=V1-2*V2+C4*V
3
15700
G3=V4-C4*V3
15750
G4=V5-C4*V3
15800
G6=S2*V2/2-S4*V
3
15900
J1=(W2+W3+C2*(W
2-W3))/2:J2=(W2
+W3-C2*(W2-W3))
/2:J3=S2*(W2-W3
)/2
16000
A=G1*E1^2+G2*E2
^2-G4*E6^2+2*(G
3*E1*E2+G5*E1*E
6-G6*E2*E6)
16100
B=J1*E1+J2*E2+J
3*E6
16200
R1=(-B+SQR
(B*B+4*A))/2/A
16300
R2=(-B-SQR
(B*B+4*A))/2/A
16400 B(1)= INT
(X(10)/E/R1/2+1
)*2
16450 B(2)= INT
(X(10)/E/R2/2+1
)*2
16470
B(3)=R1/X(10):B
(4)=R2/X(10)
16520 PRINT
#Z;"======";I;"
======"
16530 PRINT
#Z;H$;Y(I)
16550 PRINT
#Z;"R+=";R1
16560 IF A(1)<1
THEN 16650
16600 PRINT
#Z;"n+=";B(1)
16650 PRINT
#Z;"Sgm+=";B(3)
;"MPa"
16700 PRINT
#Z;"R-=";ABS
(R2)
16730 IF A(1)<1
THEN 16800
16750 PRINT
#Z;"n- = "; ABS
(B(2))
16800 PRINT
#Z;"Sgm- =
";B(4);"MPa":RE
TURN
27000 INPUT
"flex.
calculations
-y/n";G$:X$="FL
EXURAL
CONSTANTS"
27400 GOSUB
5800:X(10)=Z(0)
*E
27700 FOR I=1
TO 3:GOSUB 7000
27850
X(10)=X(10)+E*Z
(I)
27900
D=2/3*(X(10)^3-
(X(10)-Z(I)*E)^
3)
28000 FOR J=1
TO
6:V(J)=V(J)+U*X
(J):NEXT J:NEXT
I:WW=X(10)
28500
N=1:Z$="D":TT=0
:XX=1E6:U$="Nm"
:IF G$="y"THEN
GOSUB 3800
29100 GOSUB
3000
29300
X$="":N=2:Z$="d
":TT=6:XX=1E-3:
U$="(Nm)-1":IF
G$="y"THEN
GOSUB 3800
29400
K(10)=2*X(10)^3
/3:GOSUB 12000
29600 INPUT
"eng.
const.";G$:Z$="
A"
29700 IF
G$="y"THEN
GOSUB 4970
30000 INPUT
"norm.
const.";G$
30100
Z$="D*":N=1:TT=
0:XX=1E-3:U$="G
Pa":IF
G$="y"THEN
GOSUB
12300:GOSUB
3900
30500
Z$="d*":N=2:TT=
6:XX=1E6:U$="TP
a-1":IF
G$="y"THEN
GOSUB
3800:GOSUB
12400
31000 INPUT
"strength  y/n
";G$:IF
G$<>"y"GOTO
33100
31200 GOSUB
51050:PRINT
#Z;"FLEXURAL
STRENGTH"
31500
Z$="M":U$="MN":
GOSUB 13900
32300
X(0)=Z(0)*E:X(1
0)=(X(10)*1
2-3)/6
32400 FOR I=1
TO
3:A(I)=A(I-1)+Z
(I)*E:H$="angle
"+STR$(I)+"= ":G
OSUB 14200
32500
E1=E1*A(I):E2=E
2*A(I):E6=E6*A(
I):GOSUB
15500:NEXT I
33100 INPUT
"BUCKLING
y/n";G$:IF
G$<>"y"THEN
GOTO 3400
33110 GOSUB
40000:GOTO 3400
40000 GOSUB
51000:PRINT
#Z;"BUCKLING":T
Y=1E33
40010 INPUT
"length & width
in m";B,C:INPUT
"LOAD N1,N2 in
MN/m";K,L
40025 PRINT
#Z;"dim. of the
Plate(l,w,t)
";B;C;2*WW;"loa
d ratio  N2/N1
is";L/K
40040 FOR I=1
TO 5:FOR J=1 TO
5:D=(I/B)^2+(J/
C)^2*L/K
40050
TX=4*A^2/D*((I/
B)^4*V(1)+2*(V(
3)+2*V(4))*(I*J
/B/C)^2+V(2)*(J
/C)^4)
40060 IF TX>TY
THEN 40065
40063
TY=TX:M=I:N=J
40065 NEXT
J:NEXT I
40070 PRINT
#Z;"critical
load";TY;"MN/m
(";M;",";N;"
mode";M;",";N
:RETURN
50000
F=2E-16:A=1.570
79633:B= INT
(3.14159265*1E
16):I=.31830988
:I=201/64
50070
H=-.166666666:"
=.833333307E-2:
=.467653590E-2
50090
J=-.195408222E-
3:K=.275223711E
-5:L=-.23868346
4E-7:RETURN
50100
TY=TX*3.141592
5:190:TV= ABS
(TY):TS= SGN
(TY):GOTO 50150
50120 TV= ABS
(TY)+A:TS=1:GOT
O 50150
50150 IF TY =B
THEN PRINT
"error":STOP
50160 TN= INT
(TV*C+.5
50170
TT=.5*TN:IF TT=
INT (TT)THEN
TS=-TS
50180 IF ABS
(TY) TV THEN
TN=TN-.5
50190 TF=ABS
(TV)-TN*D-TN*W
50200 IF ABS
(TF F THEN
TR=TF:GOTO
50230
50220
TR=TF^2:TR=(
L*TR+K)*TR+J)*T
R+H)*TR+H)*TR
50230
TR=TF+TF*TR:IF
TS<0 THEN
TR=-TR
50240 RETURN
51000 IF Z=1
THEN RETURN
51050 PRINT
#Z;"
-":RETURN
```

SECTION IV

CONCLUSIONS

The description and the instructions for the use of the Panasonic HR-1800 Hand-Held Computer, the calculations of the stiffness and strength of symmetric laminates, are presented in this report. This package has been made very easy to use and requires no previous knowledge. Instant calculations can be made for practical use.

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